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ORIGINAL ARTICLE

Pacing accuracy in collegiate and recreational runners

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Abstract To examine runners' ability to produce a prescribed pace, we compared prescribed versus actual 400 m splits for collegiate (COL, $n = 12$) and recreational runners (REC, $n = 16$). Participants completed a VO_{2max} trial and on a 400 m track, three 3,200 m time trials. During three subsequent sessions, participants completed 800 m warm-up; then, based on their fastest 3,200 m steady pace, subjects completed six laps total at three prescribed paces: (a) 2× 400 m at 7% slower than steady pace (SLO), (b) 2× 400 m at steady pace (AT) and (c) 2× 400 m at 7% faster than steady pace (FAS). Instructions were to complete the sets of two laps in prescribed times (e.g., 75 s per 400 m) (no feedback). Deviation scores (absolute value of difference: prescribed vs. actual time) (s) for each 400 m lap were compared using a 2 (group) × 3 (trial) repeated measures ANOVA. Main effects for deviations among trials SLO (7.3 ± 6.5), AT (6.6 ± 6.9) and FAS (6.2 ± 5.7) were not significantly different ($p > 0.05$). However, group main effect for deviation scores was significantly ($p < 0.05$) lower (greater accuracy) for COL (2.9 ± 3.2 s) versus REC (9.5 ± 6.6 s). Deviation scores were also significantly different ($p < 0.05$) for SLO (COL: 3.1 ± 2.7 s, REC: 10.4 ± 6.7 s) and AT (COL: 1.9 ± 1.9 s, REC: 10.1 ± 7.2 s), with a trend for FAS ($p = 0.06$) (COL: 3.8 ± 4.3 s, REC: 7.9 ± 6.1 s). Bland–Altman plots showed better agreement (prescribed vs. actual) for COL. Experience and fitness of collegiate runners resulted in improved pacing accuracy.

Keywords Running splits · Pacing · Racing · Fitness

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Introduction

Runners often attempt to run at a desired velocity to achieve best results. A prescribed pace is thought to permit running their fastest time or achieving a time that will qualify them for a subsequent competition. Although not well-established, it has been proposed that even pacing optimizes distribution of energy resources (Foster et al. 1993). Studies investigating pacing and pacing strategies are sparse and consequently little is known with respect to pacing in sport performance. Further, the ability of runners to attain a desired velocity is not well-understood.

Performances of various kinds are often enhanced due to training-induced changes in physiological capacity (elevated VO_{2max}, higher lactate threshold, greater muscular strength). In addition to improved physiological capacity, performance may be improved through skill enhancement as a result of practice. Pacing ability is a skill and plausibly would benefit from repetition as an individual becomes better able to regulate effort to evenly pace or achieve desired splits. Often these splits might be at the direction of a coach as part of a previously devised strategy in a given race. Regarding repeated efforts, across three repeated cycling time trials (4k), Ansley et al. (2004) showed a significantly lower peak power (less of an initial spurt) for participants in the final two trials versus the initial trial. Although performance times were not significantly different, effort allocation tended toward a more even pacing strategy in successive trials indicating producing an even pace may be subject to a learning effect in some individuals. Foster et al. (1993) dictated pacing to ensure participants utilized a negative split, positive split and even pacing strategy during repeated cycling time trials (2k). Although not conclusive across all paradigms and exercise modes, in that study even pacing strategy resulted in superior performance. Others have also suggested that coaching athletes to ‘hold back’ resulted in improved performance (Firth 1998). Such an approach (altered effort allocation) would require athletes to self-pace to produce desired splits, although the accuracy of producing a requested split is unknown.

The pacing strategy adopted by elite athletes has been shown to vary based on race distance. For example, Tucker et al. (2004) evaluated world record times for 800 m, 1 mile, 5,000 m and 10,000 m running. For 800 m, a positive split was common with decreased velocity from start to finish. However, with longer distances, athletes adopted a more even strategy with an end-surge or “kick” commonly observed near completion of the event. It is unknown whether athletes intuitively select an optimal pacing strategy. However, if they do, data from Tucker et al. (2004) would challenge the notion that even pacing is always optimal. However, aggregate data alone do not allow an assessment of whether world record performances were associated with progressively more even pacing each time a record was broken. That is, successive world records may have been set using a pacing strategy which followed a pattern of negative or positive splits rather than more and more even. We emphasize that the evenness was not evaluated and therefore it is impossible to definitively conclude that this strategy is the best approach.

An important application to pacing involves achieving a prescribed pace whether involving even, negative, or positive splits as part of a strategy. This may happen when an athlete or coach has predetermined the splits they believe are required to optimize performance. The ability to produce a running velocity to optimize performance is less frequently evaluated than absolute performance time and finishing position. The ability of individuals to achieve a prescribed running velocity to achieve given race splits has not been examined. However, pacing accuracy (i.e., running prescribed splits) may be a critical component in achieving a desired performance irrespective of ideal effort allocation. This study examined the ability of collegiate versus recreational runners to produce individually prescribed 400 m splits. The primary aim was to compare 400 m split times that athletes produced to the splits that were prescribed. This approach was intended to mimic a situation in which a coach might request given splits.

Methods

Subjects

Twenty-eight physically active male and female runners were recruited for participation from local running clubs and the collegiate cross-country team. Participants were assigned to either the collegiate runners group (COL) or recreational runners group (REC). COL were current or previously competitive on a collegiate cross-country team while REC were not. Prior to data collection, subjects completed a written informed consent outlining participation requirements. All procedures were approved by the local review board for the protection of human subjects. Each participant arrived at the lab with instructions to be well-hydrated, at least 3 h post-prandial and to have abstained from caffeine and alcohol for a minimum of 24 h. Age (years), height (cm) and mass (kg) were measured and recorded using a balance scale (Detecto, Webb City, MO). Body fat percentage was estimated using skinfold calipers (Lange, Cambridge, MD, USA) and a three-site method (men: chest, abdomen, thigh; women: triceps, iliac, thigh) (Pollock et al. 1980).

VO_2 peak trial

Following descriptive data collection, each subject completed a maximal exertion treadmill (Quinton, Bothell, WA) test to determine VO_2 peak. Subjects were fitted with an appropriately sized air-cushioned face-mask (Vacu-med, Ventura, CA) and with a heart rate (HR) monitor transmitter (Polar, Stamford, CT) at the level of the sternum. The protocol began at 80.4 m/s (3 mph) at 0% grade. Every 3 min, speed was increased 26.8–40.2 m/s (1–1.5 mph) and grade was increased 2% until the subject reached 214.4 m/s (8 mph). Velocity then remained constant with grade being increased 2% per minute until the subject could not complete a given stage. With verbal encouragement provided, the trial continued until subjects achieved volitional exhaustion. Metabolic data (VO_2, VCO_2, respiratory exchange ratio, ventilation) were collected using a metabolic measurement system (Vacu-med Vista mini-cpx (silver) Vacu-med, Ventura, CA). Software designed for use with the metabolic system (Turbofit Vacu-med, Ventura, CA) was set to report mean metabolic data over 15 s time periods. The system was calibrated prior to each test with a gas of known composition. A 3 L syringe (Hans Rudolph, Kansas City, MO) was used to calibrate the system for measurement of ventilation. HR response was collected using a Polar chest strap transmitter and wrist receiver (Polar). Ratings of perceived exertion (RPE) were collected during the last 15 s of each stage using the original Borg category (6–20) scale (Borg 1982). The RPE scale was verbally anchored with subjects being told "6" corresponded to seated rest and "19–20" corresponded to maximal exertion. Each subject was required to meet at least two of these four criteria for achievement of VO_{2max}: (a) RPE $\geq$ 18, (b) RER $\geq$ 1.1, (c) plateau of VO_2 with increased workload and (d) >85% of age-predicted maximum HR (Maud and Foster 2006).

3,200 m time trials

As part of a separate study, individual participants completed three 3,200 m runs on three separate days on a 400 m track with instructions to complete the distance as fast as possible. Verbal encouragement was provided but information regarding split times was not. Participant's mean 400 m lap time in seconds was calculated using their fastest 3,200 m trial. Because runners may be coached to achieve certain lap splits, this split time was used as a reference for prescribing desired pacing velocity.

Pacing time trials

Participants reported to the track with previous instructions to arrive well-rested (no strenuous physical activity for minimum of 24 h) and well-hydrated. They were permitted to stretch as desired before completing a warm-up of 800 m at a self-selected intensity. Then, in sequential order (back to back without recovery), participants completed: (a) 800 m (2 laps) at a time 7% slower than their reference lap time (SLO), (b) 800 m at/matching their reference lap time (AT) and (c) 800 m at a pace that was 7% faster than their reference lap time (FAS). Instructions were to run the given distance at a prescribed duration per lap (e.g., complete 2 laps at 82 s each). Prescribed laps were completed immediately upon finishing the warm-up with no recovery. No feedback was given during the trials except for reminder of the prescribed lap time which was given once per lap. Lap times were recorded to the nearest second.

Statistics

To compare the accuracy of completing prescribed lap times between COL and REC groups and for SLO, AT and FAS laps, a deviation score was calculated for each 400 m split (absolute value of actual vs. prescribed lap time). That is, each 400 m lap was viewed as an attempt to create the prescribed pace. Deviation scores (s) were compared using a 2 (group) $\times$ 3 (trial) ANOVA (Greenhouse–Geisser correction for unequal variances was applied). When necessary, a Sheffe post hoc test was used. Results were considered significant at $p \leq 0.05$. For further analysis of the agreement between prescribed and actual splits, Bland–Altman plots (Bland and Altman 1995; Altman and Bland 1983) were created for SLO, AT and FAS deviations for group. For Bland–Altman plots for each group and each trial, the differences between actual and prescribed times for each subject were calculated with the sign of the deviation observed. The group mean and standard deviation for this measure were determined. The mean difference was plotted along with the limits of agreement.

Results

Descriptive data for COL and REC are presented in Table 1. Main effects for deviation scores showed significantly smaller (more accurate) deviation scores for COL compared to REC (Table 2). There were no significant main effects for deviations among SLO, AT and FAS trials (Table 2). Follow-up testing showed significantly smaller ($p < 0.05$) deviation scores for COL (vs. REC) for SLO and AT ($p < 0.05$) with FAS approaching significance ($p = 0.06$) (Table 2). Bland–Altman plots display actual versus prescribed times for COL and REC for SLO (Fig. 1), AT (Fig. 2) and FAS (Fig. 3). Confidence

Table 1 Descriptive characteristics (means ± SD) for collegiate (COL) and recreational (REC) runners

Variable	COL	REC
Age (years)	25.4 ± 4.6	23.2 ± 7.2
Ht (cm)	177.8 ± 3.0	172.7 ± 6.4
Mass (kg)	63.0 ± 3.8	70.0 ± 6.6
Body fat (%)	5.3 ± 1.8	13.6 ± 3.2
VO_{2max} (ml/kg min)	66.0 ± 5.4	44.0 ± 6.0

Table 2 Mean deviation scores (absolute value of actual vs. prescribed lap time) for COL and REC for SLO, AT and FAS

	SLO	AT	FAS	All trials
COL	3.1 ± 2.7**	1.9 ± 1.9**	3.8 ± 4.3‡	2.9 ± 3.2*
REC	10.4 ± 6.7	10.1 ± 7.2	7.9 ± 6.1	9.5 ± 6.6
Groups pooled	7.3 ± 6.5	6.6 ± 6.9	6.2 ± 5.7	

Values are means and standard deviations. SLO versus AT versus FAS: no significant main effect

* COL versus REC: $p < 0.05$ main effect

** COL versus REC: $p < 0.05$ within SLO and AT

‡ COL versus REC: $p = 0.06$ within FAS

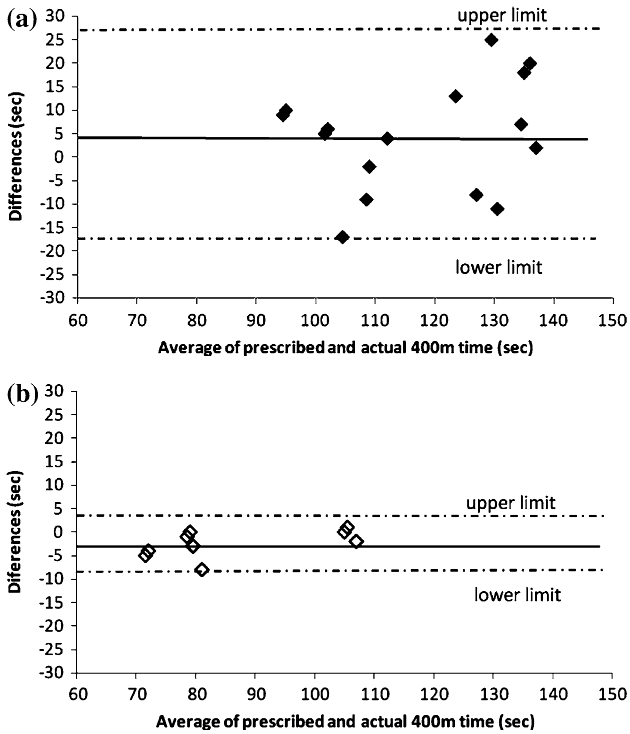

Fig. 1 **a** Bland–Altman plots for REC for SLO. **b** Bland–Altman plots for COL for SLO

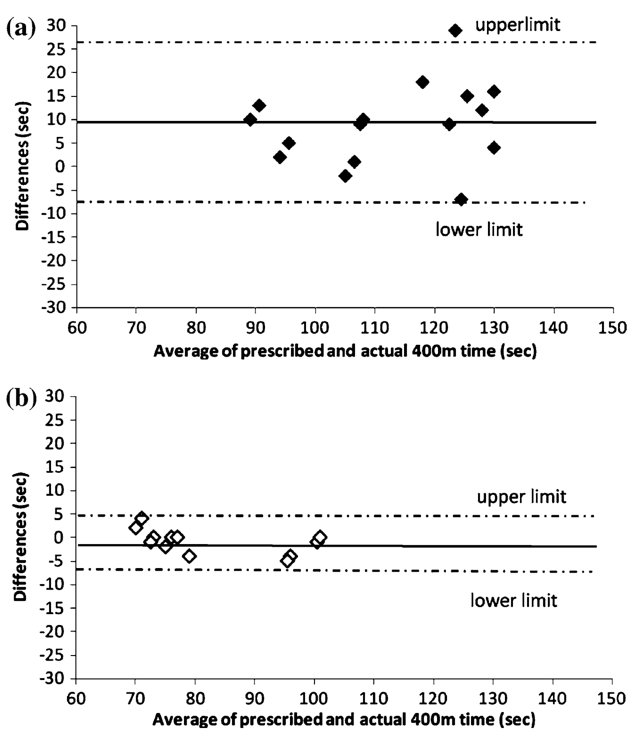

Fig. 2 **a** Bland–Altman plots for REC for AT. **b** Bland–Altman plots for COL for AT

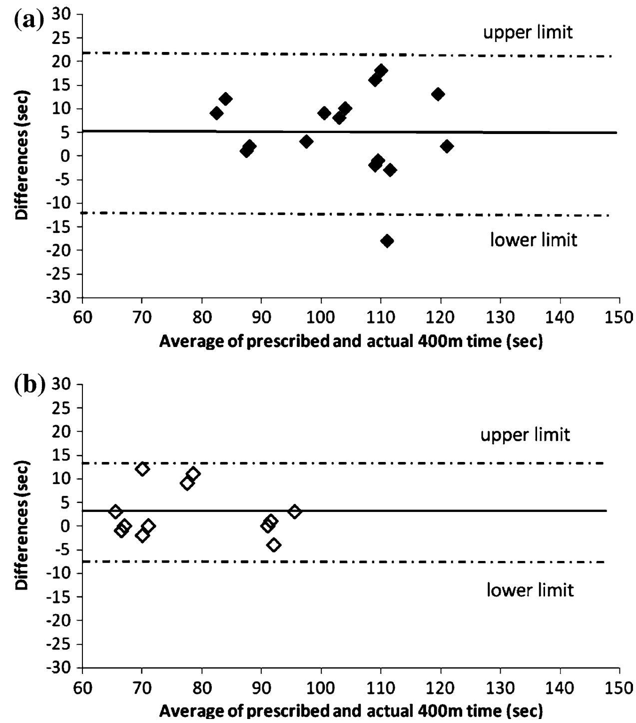

Fig. 3 **a** Bland–Altman plots for REC for FAS. **b** Bland–Altman plots for COL for FAS

intervals clearly show better agreement (actual vs. prescribed) for COL for all three trials. For example, the limits of agreement [SLO (REC: 45 s, COL: 11 s), AT (REC: 33 s, COL: 5 s), FAS (REC: 35 s, COL: 20 s)] were much tighter for COL in each trial with mean error also much lower [SLO (REC: 4.5 s, COL: −2.9 s), AT (REC: 9.0 s, COL: −0.9 s) FAS (REC: 4.9 s, COL: 2.7 s)] (Figs. 1a, b, 2a, b, 3a, b).

Discussion

Certain pacing strategies may be employed as part of a predetermined race strategy designed to win a race or qualify for an event. However, pacing ability is not well-understood. Of particular interest in the current study was an athlete's ability to accurately produce and maintain a desired pace (i.e., running velocity) which may influence their performance. This study compared collegiate and recreational runners' ability to run at three different prescribed paces. Pace was prescribed for each individual as a desired 400 m split with their 3,200 m time trial performance used as a reference.

These results indicate that pacing accuracy was clearly superior in more experienced (collegiate) versus less experienced (recreational) runners. We used deviation scores as an indicator of accuracy with greater deviation indicating less precision and smaller deviation indicating greater precision. Table 2 shows the mean of deviation scores for all trials that were approximately three times higher for REC than COL. It is noteworthy also that the deviation scores were reported per 400 m meaning that, if this deviation held true, the accuracy per mile would be compounded if extrapolated to 1,600 m (~1 mile). Obviously, the greater running experience for COL at least partially explains enhanced pacing accuracy. Being current or former members of a collegiate cross-country team, this group (COL) was likely to have competed more frequently in settings similar to the paradigm in the current study (running on a track). Conversely, recreational runners are likely to have competed less frequently on a track. Data regarding this contention were not collected.

It is reasonable to assume that pacing may be improved through repetition. Ansley et al. (2004) showed adoption of a progressively more even pace across three repeated 4 km cycling time trials. Although not definitive, even pacing has been proposed to offer athletes the most advantageous distribution of energy reserves (Foster et al. 1993; Firth 1998). In other research in our lab (Sapp et al. 2007), collegiate and recreational runners completed three 3,200 m running time trials on a track. The study showed that all runners regardless of gender or status (collegiate vs. recreational) began the 3,200 m trials faster than their adopted steady pace and ended the trials with a kick where velocity was faster than their 3,200 m steady pace. We suggest this observation may be the result of conditioning. That is, in a race setting where runners are grouped together at a starting line, many likely opt for a burst of speed early in an effort to avoid being trapped in a bad position during the early portion of a race. It is plausible that runners followed this pattern even in the current (time trial) paradigm. Across 3,200 m time trials, no changes in evenness were observed for collegiate runners. Male recreational runners adopted an ‘all-out’ pacing strategy in the initial trial as well as the subsequent two trials indicating this group of recreational runners did not adjust pacing strategy. While Ansley et al. (2004) suggest that a learning effect may be observed following one trial in cycling, Sapp et al. (2007) suggest that three 3,200 m trials were insufficient to observe a learning effect in recreational runners. Visual observation in Sapp et al. (2007) as well as the current study nevertheless demonstrates more even pacing among collegiate runners suggesting that either higher fit runners (see VO_{2max}, Table 1) for some reason pace more evenly or progression from a more varied to a more even pacing strategy requires more than three trials in REC runners. The current design required runners’ to attempt to produce the prescribed paces back to back and always from slowest pace to fastest. It is possible that this approach could have influenced results in that the order in which velocities were requested ensured that runners would run each prescribed velocity faster than the previous as they would reference the previous two laps (which were slower) to increase their effort to achieve a faster velocity. If results were affected in this manner, a systematic and consistent difference between prescribed and produced pace would have been expected within subjects. Examining the deviation scores indicates this is possible. Future studies should request various velocities in random order to better understand runners’ acute ability to create a given pace.

COL were more accurate for all three situations (SLO, AT, FAS) (Table 2). However, the most accurate production (smallest mean deviation score) occurred when subjects were asked to produce similar running velocity as their best initial 3,200 m trial (e.g., the AT trial) with runners only deviating from the prescribed 400 m time by approximately 1.9 s. This is approximately a 33% smaller deviation than that observed for COL for SLO (3.1 s) and FAS (3.8 s). This also suggests that experience helps explain greater accuracy for COL. The AT trial was conducted with times prescribed exactly at the runners best (of three) 3,200 m time trials. This means runners during the AT laps were essentially instructed to run at the velocity at which they were most accustomed to running during the previous trials as well as if they were attempting a personal best time (vs. a velocity alternatively prescribed slightly faster or slower). It is noted that while the lowest deviation scores (greatest accuracy) were observed for AT for COL, this was not observed for REC. In fact, the lowest deviation scores for REC were observed for FAS (Table 2). However, comparatively speaking, even the most accurate trials for REC were considerably less precise (7.9 s per 400 m) than for COL (1.9 s per 400 m).

Tucker et al. (2004) evaluated world record times for 800 m, 1 mile, 5000 m and 10,000 m running and concluded that distance influences the pacing strategy adopted. More even pacing was observed as distance increased. Only in the 800 m distance did athletes run positive splits (running progressively slower as the race progressed). For 1 mile and greater distances, race splits were similar (even) but still included an end-spurt (kick). From these data, it is plausible that optimal times for the 3,200 m distance in the current study would have been achieved through running even splits. It is hypothesized that COL displayed greater awareness of their personal capacity and consequently were more effective in regulating their effort to achieve even splits. However, from the current study, it cannot be determined what level of fitness or repetition is required to develop this ability.

Bland–Altman plots were utilized to evaluate agreement between prescribed and actual 400 m split times. Times were prescribed at three levels and runners of all abilities would be expected to demonstrate the capacity to systematically increase effort corresponding with increasingly faster prescribed times. This design would ensure reasonable relationship with prescribed and actual times. However, evaluating relationships can be misleading particularly when agreement is the primary issue (Bland and Altman 1995; Altman and Bland 1983). Bland–Altman plots for prescribed versus actual split times clearly show greater agreement for COL for all prescribed conditions: SLO (Fig. 1), AT (Fig. 2) and FAS (Fig. 3) further confirming the superior ability of COL to produce prescribed running velocities. It is important to point out that the current investigation did not examine physiological correlates during pacing trials. It is suggested that future investigations include physiological measures (heart rate, lactate) in an attempt to identify factors associated with pacing ability as this is a worthwhile inquiry. This study, however, focused solely on the ability of runners to create prescribed paces (pacing accuracy).

It is important to point out that pacing is not synonymous with racing. The current design did not put runners against each other as would be the case in competitive environments. Racing would differ from pacing in that many variables could influence outcomes. For example, races may sometimes include a 'rabbit' who voluntarily sacrifices their own performance for the benefit of a teammate. Also, if runners are well-aware of their competition and are confident that they are superior runners, they may choose to simply stalk the inferior group of runners until a chosen time and then pull away for the lead and ultimately the victory. This would be a situation in which even pacing is considerably less important than the racing strategy devised prior to the event. Sir Roger Bannister stated that pacing was the key to breaking the 4 min mile (Bannister 2002). For Bannister's sub-four-min mile, the mean 400 m split was 59.85 s with sequential splits of 57.4, 58.2, 64.9 and 58.9 s. Using the current approach, the deviation score for this effort was 2.5 s which is very similar to the deviation scores for COL in the current study (Table 2). While Bannister utilized other runners to pace him on each lap, his effort supports the notion that even pacing is effective. Bannister's effort also arguably reflects reasonably effective ability to create desired splits. However, this ability may have rested with his pacers.

To our knowledge, this study is the first to evaluate runner's ability to produce a given pace (running velocity) using prescribed 400 m lap times. Results suggest that the greater experience and possibly fitness level of collegiate cross-country runners permitted greater precision in producing prescribed lap times. This conclusion is supported by smaller deviation scores (Table 2) as well as tighter confidence intervals on Bland–Altman plots for COL for SLO, AT and FAS (Figs. 1, 2, 3). Further work is warranted evaluating the time course of improved (i.e., more even) pacing ability as well as other factors which potentially influence runners' ability to regulate effort to accurately produce a given running velocity. In particular, physiological measures should be examined in future investigations in an attempt to more clearly identify the reasons behind pacing accuracy. In conclusion, the current study extends the knowledge regarding pacing ability suggesting collegiate runners (vs. recreational runners) can more precisely produce a prescribed running velocity based on 400 m lap time.

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